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Effects of cowmilk butter and honey wax coatings and storage temperature on the physicochemical, sensory attributes, and quality of oranges (*citrus sinensis*) cv sweet oranges.

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Research

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ABSTRACT

This study evaluated the efficacy of honey and cowmilk butter used as a coating material for oranges and samples were periodically assessed for internal and external quality. The evaluation about the percentage weight loss, fruit quality characteristics (TA and TSS levels), and sensory evaluation (fruit firmness, taste, and overall acceptability) were assessed and recorded at intervals of 2 days for 14 days of storage. The results showed that the sweet oranges treated with cowmilk butter were better when compared with honey coatings and stored at 7ºC at room temperature ≤25ºC. Fruits coated with cow milk butter and held at 7°C produced the lowest loss in weight of 4.1%, and delayed loss of fruits firmness. The TSS content was 7.8 ºbrix, and TA level declined to 5.4 citric acids. Fruits coated with honey at 7ºC recorded 15.1N for firmness, TSS of 8.2 ºbrix, 4.4 citric acids, and a weight loss of 10.5%. Uncoated oranges had the highest weight loss, lowest firmness level, increased TSS content, and the highest decline in TA level during storage. Oranges coated with cowmilk butter held at ambient conditions had 11.7% weight loss, firmness of 12.4N, TSS of 8.5 ºbrix, and 5.6 citric acids. Uncoated fruits held at ambient conditions had the highest weight loss of 39.1%, firmness of 12.7N, TSS of 9.9%, and 6.2 citric acids. Generally, the organoleptic evaluation found that the highest score of overall acceptability value was observed in cowmilk butter-coated fruits at 7°C storage.

Keywords: Coatings, *citrus sinensis*, postharvest, storage temperatures, sensory qualities

1. INTRODUCTION

Citrus fruit (Citrus *Sinensis*) is often stored for long periods due to the seasonal nature of the harvest period and the need to sell the fruit in regional markets over extended periods (Hervalejo et al., 2021). Citrus originated in southeast Asia, spreading and establishing through all continents (Langgut, 2017a). Citrus trees are mainly grown between latitudes 40 N and 40 S throughout the tropical and subtropical regions (Langgut, 2017a: Langgut, 2017b). Citrus is an important diet for many people because it supplies vitamin C and polyphenols, flavonoids, phenols, and carotenoids which are very useful for human health (Liu et al., 2022; Lu et al., 2023). The quality of citrus fruit may be defined as the composition of those characteristics that differentiate individual units of the fruit, and have significance in determining the degree of acceptability of that unit to the consumer (Kowalska et al., 2023). Consumers are influenced by quality attributes such as fruit weight loss, taste, firmness, sugar level, peel colour, and appearance to purchase. Fruits are usually coated to prevent moisture loss, protect the fruit from bruising during shipping, maintain quality, and increase their storage life (Hussein et al., 2020). Dhemre and Wasker (2003) reported that citrus fruit coated had a better appearance and, therefore acceptability relative to control fruit during storage.

Biochemical changes of citrus fruit are affected by location, cultivar and rootstock, mineral nutrition, climate, and postharvest treatment and storage conditions (Danai et al. 2012). Although citrus fruits are climacteric fruits higher temperatures and longer storage duration can affect maturation (Lester and Hodges, 2007). Studies showed that reducing postharvest transpiration is the most important factor in increasing the storage life of citrus. Water loss because of transpiration not only causes wilting, softening, and drying up of citrus fruit can but lead to deterioration and reduce the appearance of the fruit. During the process of fruit handling in the packinghouse, most of the natural wax is removed during washing. These natural protectants must be replaced by coating. The coating also imparts an attractive shine to the peel (Hagenmaier and Shaw, 1991). Coating treatments on citrus alter the interior atmosphere of fruit and extend the storage life of citrus fruit (Mannheim and Soffer, 1996). It is reported that surface coating can reduce citrus fruit weight loss by up to 50%, depending on coating type and concentration (Hassan et al., 2014). Although many fruits develop waxy coatings on their epidermis (Hassan et al., 2014). Wax coatings have been shown to maintain the postharvest quality of fruit by limiting gas exchange and reducing water loss and skin discoloration (Baldwin et al., 1999; Hagenmaier and Baker, 1993) and contribute enormously to preserving the freshness of the fruits and improve the appearance (Baldwin, 1994). A study by Seehanam et al. (2010) indicated that coated Tangerine fruits showed higher gloss and better visual appearance when compared with non-coated fruit. Orange fruit coated with pure coconut oil, liquid paraffin wax, and castor oil maintain natural light green colour during storage (Abhay et al., 2012), due to retardation of senescence process, slowed metabolic as well as enzymatic reaction activities and less degradation in the colour pigment which slows the change peel colour.

But Muhammad and Nadeem (2011) indicate that coating treatment retained maximum total soluble solids (TSS) in citrus during cold storage. A similar trend was observed in citrus fruit room temperature conditions, where coated fruits were observed to have the highest TSS content than control fruits (Mahajan et al., 2013; Sidhu et al., 2009) and sustained fruit firmness by decreasing respiration and transpiration, slowing ripening and senescence, and delaying the degradation of the cell wall (Baldwin, 1994; Mahajan et al., 2013). However, titratable Acidity (TA) level can gradually decrease with increasing storage period on citrus fruits. Danai et al. (2012) observed that tangerine fruits when coated with 'Fomesa' and 'Zivdar' could not show differences in TA levels as compared to non-coated fruit. Jagadeesh et al. (2001) reported that higher acidity of lime fruit was retained under pure coconut oil coating due to lesser availability of oxygen to fruit in later stages of storage. A plethora of studies have investigated the effects of storage temperatures on postharvest treatments on oranges fruits in terms of weight loss, appearance, internal

qualities, firmness and the presence of ethanol and acetaldehyde (Peeples et al., 1999; Pérez-Gago et al., 2002; Petracek et al., 1998; Porat et al., 2005). However, few have attempted to relate post-combine effects of coating and storage conditions on fruit quality as measured by sensorial analysis performed by taste panelists (Hagenmaier and Baker., 1994; Mannheim and Soffer, 1996; Shi et al., 2005). Evaluating the sensorial attribute of fresh produce citrus fruits can be used to identify optimal harvest maturity, evaluate flavour quality, determine optimal storage and handling conditions, and measure flavour quality over post-harvest (Baldwin, 2002). Thus, the objective of this research is to determine the effects of cowmilk butter and honey surface coating on the storage life of orange fruit during cold storage and ambient temperature.

2. MATERIALS AND METHODS

2.1 Materials and experimental design

Four hundred and fifty (450) matured sweet oranges were purchased from a commercial farmer in Techiman, Ghana, and packed in partitioned plastic crates to avoid mechanical damages and quickly transported to the postharvest laboratory of Dr. Hilla Limann Technical University in the Upper West Region of Ghana. Fruit was cleaned with soft tissue and sorted of all defects and completely randomized. The experiment consisted of two treatments, i.e., honey treatment and cow milk butter treatment as coatings, which was done by rubbing twenty millilitres (20ml) of honey wax or cowmilk butter on each fruit. The other lot of fruit was not coated and observed as control fruits. Ninety citrus fruits were used for each treatment with 30 fruits comprising a treatment unit (a replicate) of the experiment with control fruit also having the same number of fruits. While the remainder of the fruits (90) were used for zero-day assessments. After coating the fruit and air drying for four hours, the fruits were placed at 7°C at a relative humidity (RH) of 80-85% and room temperature (≤25ºC, or RH of ≤55) storage. Assessment of the experiment was done every 2 days for 14 days, thus days 0, 2, 4, 6, 8, 10, 12, and 14, Fruits were evaluated for physicochemical parameters, sensory qualities and overall flavour acceptance.

2.2 Determination of fruit firmness and weight Loss

The firmness of fruits was measured by using a penetrometer (Wagner Model FT 327 having 28 lbs capacity). In doing this, the plunger was inserted into the peel of the fruit, and the reading was noted in Newton (N). Weight loss of fruits was measured every two days of the experiential period using a digital measuring scale. Weight loss values in percentage were determined by deducting the initial weight (W_0) from the final weight (W_t) and dividing the initial weight (W_0) and multiplying by 100%, i.e.,

$$\frac{Wo-Wt}{Wo} \times 100\%$$

2.3 Determination of internal quality parameters

The hand-held sugar refractometer was used in determining the sugar content. The prism of the refractometer was cleaned and a drop of the juice was placed on the prism and closed. The total sugar content (° Brix) was read off the scale of the refractometer when held close to the eye per the method of the Association of Official Analytical Chemists (AOAC).

Ten (10ml) of the juice was pipetted into a conical flask and 25ml of distilled water was added as described by AOAC. Two hundred millilitres (200ml) of 0.1N NaOH was poured into a burette and titrated against the sample in the flask using three drops of phenolphthalein as an indicator. It was titrated until a pink colouration was observed and the corresponding burette reading was taken. Titre values were obtained by dividing the sum of three consistent burette readings of the same sample of juice by three. The percentage of citric acid was calculated using the following formula. TA % =

$$\frac{Titer\ Value \times 0.0064}{Volume\ of\ juice} \times 100$$

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2.4 Sensory evaluation

The sensory analysis was carried out using ten untrained panellists from the staff of Dr. Hilla Limann Technical University. The sensory qualities evaluated were taste and overall consumer acceptability. The orange coated with Honey coatings and Cowmilk butter coatings and stored at 7°C and ambient (≤25ºC)

were cut and served in clean plates to individual panellists with serial labels. The order of presentation of samples to the panel was randomized, and distilled water was provided to rinse the mouth between evaluations of the samples. The sensory attribute was assessed based on the method of Marcilla et al. (2006) with slight modification. The off-flavours intensity was scored on a 6-point category scale (0=none and 5=strong). Orange like-flavour was scored on a 9-point hedonic scale (1,2,3=low quality; 4,5,6=acceptable quality and 7,8,9=high quality). All sensory evaluations were conducted in individual booths under daylight at room temperature.

2.5 Statical analysis

Analysis of variance (ANOVA) was performed on the data for each quality variable to determine the significance of the effects of coating treatments and storage temperature on fruit quality. Duncan's Multiple Range Test (DMRT) was used to establish if there were significant differences among the treatments. Significance tests were set at $p \leq 0.05$.

3. RESULTS AND DISCUSSION

3.1 Weight loss

This study was conducted on weight loss of orange fruits using honey and cowmilk butter as coating material compared with control revealed that there was a general increase in weight loss of perishables as storage time progressed. The results showed that coating and storage temperature together demonstrated to have a significant effect on weight loss of orange fruits at $p < 0.05$ during storage compared with control fruit. The effects of coatings on the citrus fruits were consistent but uncoated fruits held at ambient (NA) and uncoated fruits stored at cold storage (NF) had significant weight probable due to water losses. Oranges treated with cowmilk butter and held at 7ºC and ambient temperature (HA) reduced weight loss in fruits but oranges treated with honey and stored at 7ºC and ambient temperature (HA) greatly reduced weight loss throughout the storage period (Fig. 1). The effects of coatings and storage temperatures together have controlled the evaporation of water from the fruit by providing an additional barrier covering micro pores and providing equilibrium of moisture between the fruit surface and the immediate surroundings. The current findings partially agreed with Sugri et al. (2010); Danai et al. (2012) and Muhammad and Nadeem (2011) who demonstrated that waxed citrus fruits showed reduced weight loss during storage and as compared to the control. The increase in weight loss of control fruits was due to the high rate of transpiration and respiration whilst minimum weight loss in fruits treated with honey coated could be a result of coating acting as a barrier between the inner and outer environment of the fruit, which is in agreement with the findings by Muhammad and Nadeem (2011). Studies conducted by Arowora et al. (2013), and Hassan et al. (2014) on the effect of coating on weight loss of citrus held at lower temperatures had lower percentage weight loss than those at ≤25°C as the storage progressed.

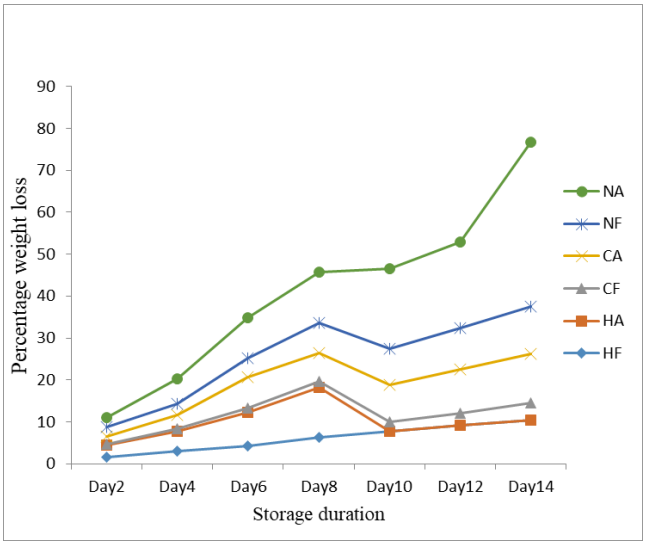

Figure 1. Effect of wax coating on the weight loss percentages of sweet oranges during storage at room temperature, ≤25°C and cold storage of 7°C. Fruits were coated with honey wax and cowmilk butter at similar concentrations. Each point represents the mean ± SE of three replications.

3.2 Fruit firmness level

The results on the firmness of orange fruits coated with honey and cow milk butter stored at 7°C and ambient temperature of ≤25°C indicated that as the storage period progressed. The firmness level of fruits coated with honey, cow milk butter, and uncoated recorded fluctuation. The fruits treated with

honey as coating material held at 7°C on day 0 recorded 28.3N, while on day 2, a significant decline in firmness of 8.5N. Citrus fruits coated with honey held at room temperature for the study recorded firmness of 29.1N on day 0, recorded at 10.0N. On days 2, 4, 6, and 8 the samples recorded 28.7N, 35.1N, and 32.6N respectively, where the fruits coated with honey held at room temperature got terminated. The uncoated fruits which were regarded as control held at both 7°C and room temperatures like the treated fruit also recorded fluctuation in fruit firmness. The effects of coatings on the citrus fruits fluctuated but uncoated fruits held at ambient (NA) and those fruits kept at cold storage (NF) were significantly less firm probable due to loss of water from fruits except for days 10 and 12 where firmness increased due fruits caking because of water loss. Oranges treated with cowmilk butter and held at 7ºC and held at ambient conditions (HA) maintained fruit firmness but oranges treated with honey and stored at 7ºC and ambient temperature (HA) significantly delayed loss of fruit firmness as shown in Figure 2. A study demonstrates that the coating of citrus has been shown to reduce cell wall loosening and respiration rate which in turn increases the cell integrity and maintains fresh fruit firmness (Ladaniya and Sonkar, 1997). As fruit firmness declines during storage, it has been found that the degree of ripening increases due to the action of pectolytic enzymes (Muramatsu et al., 1996), which is consistent with the statement that loss of pectic elements in the middle lamella of the cell wall is a key factor in the ripening process that leads to the loss of cell wall integrity thus cause loss of firmness and softening (Mahajan et al., 2013).

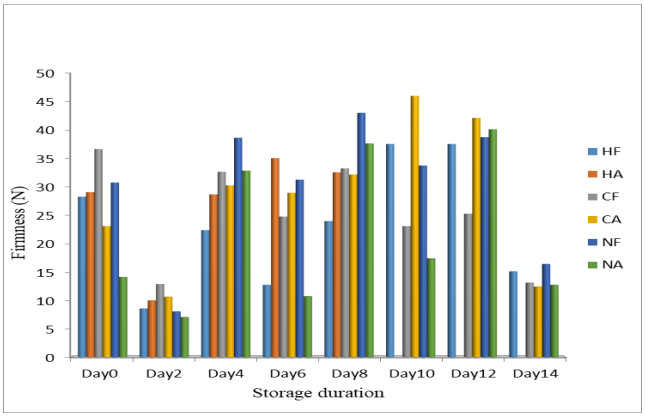

Figure 2. Effect of wax coating on the Fruit firmness of sweet oranges during storage at room temperature, ≤25°C, and cold storage of 7°C. Fruits were coated with honey wax and cowmilk butter at similar concentrations. Each point represents the mean ± SE of three replications.

3.3 Total soluble solids

There was a significant effect of coating and storage conditions on the citrus fruit during storage. Orange fruits coated with cowmilk butter and held at 7ºC and held at ambient conditions (HA) inhibited an increase in TSS content, but there was a slight increase in TSS in oranges treated with honey and stored at 7ºC most especially in fruit treated and stored at room temperature (HA), which were terminated on day 8 of storage (Fig. 4). The TSS greatly increased in uncoated fruits held at ambient (NA) and fruits held at 7ºC storage (NF). The results of this study revealed that sugar levels generally increased as storage time prolonged, which is consistent with the finding of Obenland et al. (2008) where SSC had increased as storage prolonged, while TA level had decreased, leading to a progressive increase in the SSC/TA ratio as storage time advanced. This is due to continuous metabolic activities such as ripening, hydrolysis of starch to soluble sugars, and the conversion of starch to sugar. Previous investigations have indicated that during fruit ripens there would be an increase in sugar content (El-Anany et al., 2009; Sabir et al., 2004). The current study demonstrated that coating has a significant effect on the sugar contents of stored orange fruits at $p < 0.05$. However, storage temperature did not have a significant effect on the sugar levels of the orange fruits during storage (Fig. 3 and 4). The findings conform to Baraiya et al. (2016); Debeaufort et al. (1998) and Pretel et al. (2006) who found that an increase in total soluble solids (TSS) was more pronounced in control fruits but was significantly delayed in coated fruit. This result agreed with the finding by Muhammad and Nadeem (2011), where coating treatment retained maximum TSS in citrus fruits. However, the current findings disagreed with Ali et al. (2016) and Seehanam et al. (2010) who reported a similar non-significant effect of different coatings on TSS content observed in 'Sai Nam Pheung' tangerines during long-term storage. It has also been ob-

served that wax coating does not influence the TSS level of 'kinnow' mandarin fruits (Muhammad et al., 2015). It has been reported that citrus fruit stored at a higher temperature (≤25ºC) increased the TSS of fruits during storage in the current study, which is consistent with the finding of Marcilla et al. (2006) where elevated storage temperature increased SSC of Valencia Late Frost oranges during storage.

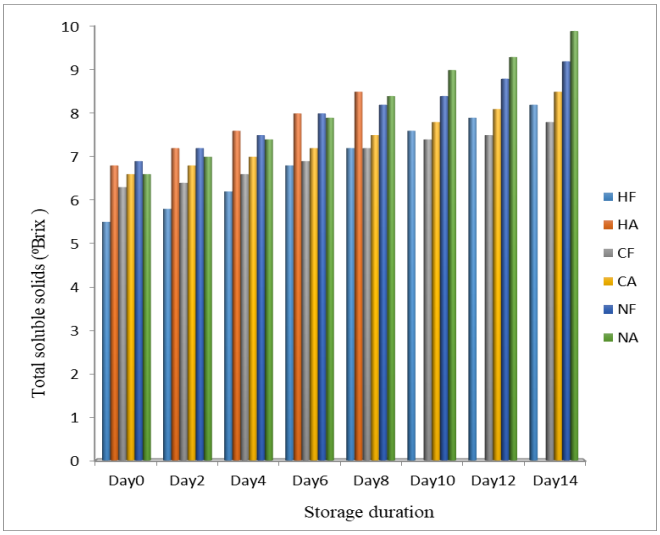

Figure 3. Effect of wax coating on the total soluble solids of sweet oranges during storage at room temperature, ≤25°C, and cold storage of 7°C. Fruits were coated with honey wax and cowmilk butter at similar concentrations. Each point represents the mean ± SE of three replications.

3.4 Titratable acidity

Titratable acidity values gradually decreased with increasing storage periods for all units of treatments. The results from the study indicated that neither coating nor temperature could produce a significant effect on the titratable acidity of the stored orange fruits. The titratable acidity of coated and non-coated tangerine fruits decreased with an increase in storage duration. It has been reported that a decrease in acid content in citrus fruits is caused a result of the conversion of organic acids to form sugar storage (Wills et al., 1998). Uncoated fruits held at ambient (NA) in this study had a higher titratable acidity however, there was no significant difference between those fruits and fruits coated with honey coatings held at 7ºC (HF) and the effect of other treatments at the end of storage, as indicated in Figure 4. These results conform with Danai et al. (2012) who observed that tangerine fruits when coated with 'Fomesa' and 'Zivdar' could not show differences in titratable acidity as compared to other coated fruits. The maintenance of titratable acidity on fruit coated with cow milk butter agreed with results by Baldwin et al. (1994); Arekemase et al. (2011) and Mahajan et al. (2013) where coatings create a modified atmosphere and limit the exchange of gases thus reducing the amount of oxygen reaching to the interior of fruit that prevents the oxidation of ascorbic acid. Similarly, Jagadeesh et al. (2001) found a higher acidity of lime fruit was retained under pure coconut oil coating which was attributed to lesser availability of oxygen to fruit in later stages of storage. The TA level decreased significantly over time, probably due to the rise in the SSC of juice (Fig. 4). This result agreed with the finding of Harker et al. (2002) who reported a sensorial declined in TA due to higher temperature storage conditions.

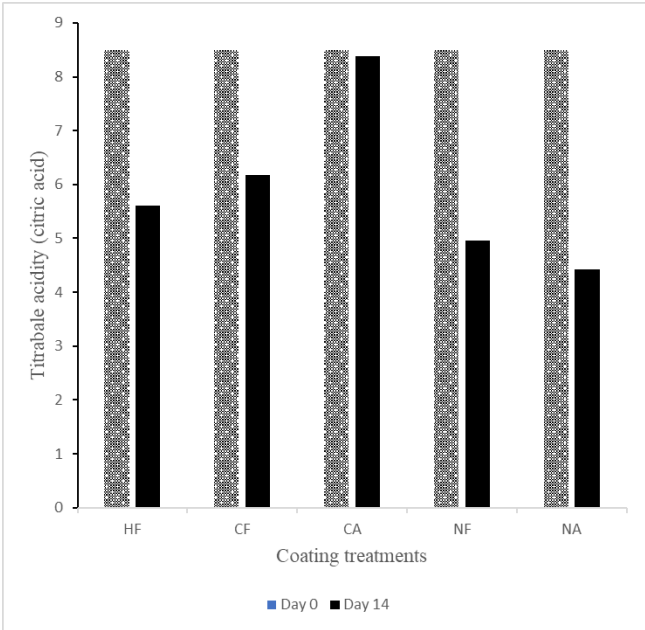

Figure 4. Effect of wax coating on the titratable acidity of sweet oranges during storage at room temperature, ≤25°C, and cold storage of 7°C. Fruits were coated with honey wax and cowmilk butter at similar concentrations. Each column represents the mean ± SE of three replications.

3.4 Blind taste test

The organoleptic value of taste decreases with the advancement of the storage period in all treatments. Results available for taste from the sensory evaluation conducted revealed that coating nor temperature could not produce a significant effect on the taste of orange fruits which supports the findings of Danai et al. (2012) that coating treatments did not show any effect on the sweetness of tangerine fruit. However, results obtained on taste revealed that orange fruits coated with cow milk butter at 7ºC performed better recoding 50% of panellists scoring it sweet when compared to the other treatments as shown in Figure 5. The better performance is attributed to the ripening process where acids are degraded, sugar content increases, and the sugar-acid ratio achieves a higher value making the fruit sweet. The increase in sweetness could also be attributed mainly to the breakdown of starch into water, soluble sugars, sucrose, and glucose during ripening, and confirmed by the result of Arowora et al. (2013) who indicated that, at the beginning of the ripening process, the sugar- acid ratio is low because of low sugar content and high fruit acid content, this makes the fruit taste sour. However, fruits coated with cow milk butter held at 7°C, were to have better taste and were mostly accepted by panellists compared to the other treatments. This performance could be attributed to maintaining the cosmetic appearance, reducing metabolic activities of fruits, and hence their acceptability. This effect could also be due to delay in fruit ripening, uniform colour development in fruits (Abhay et al., 2012; Jagadeesh et al., 2001; Mahajan et al., 2013).

In our study, the panelists were given a short training to able to differentiate between sweetness, and sourness as separate tastes despite both flavours may interact with each other. The perception of sugar can be accentuated by the presence of acids, and also some aromatic compounds that impart a sweet flavour perception (Malundo et al., 1995). The panelists met after each tasting session and discussed their results, and difficulties and asked for additional samples. The result showed that the responses of these subjects could be biased, perhaps due to insufficient training. However, the main objective of using trained panellists to do the taste test was to obtain reliable, valid sensorial, and reproducible data (Costell, 1992). Increased storage temperature in the present study reduced the orange-like flavour of the oranges and increased the presence of off-flavours over storage, thus having a negative impact on the sensorial quality of the fruit, as reported in a previous study in Valencia Late Frost oranges stored at 5, 15, 20 and 25 ºC for four (4) weeks of storage (Marcilla et al., 2006).

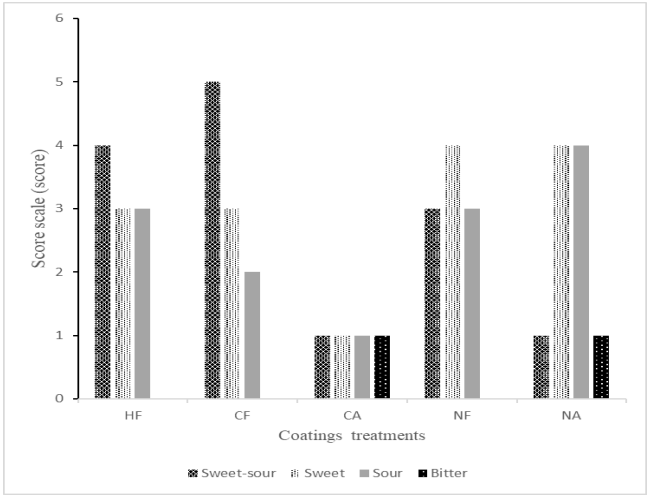

Figure 5. Effect of wax coating on the taste test of sweet oranges during storage at room temperature, ≤25°C, and cold storage of 7°C. Fruits were coated with honey wax and cowmilk butter at similar concentrations. Each column represents the mean ± SE of three replications.

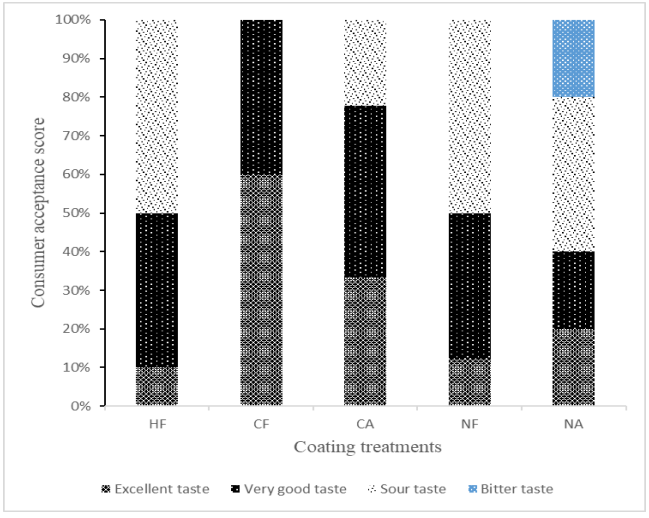

Figure 6. Effect of wax coating on the consumer acceptance of sweet oranges during storage at room temperature, ≤25°C, and cold storage of 7°C. Fruits were coated with honey wax and cowmilk butter at similar concentrations. Each column represents the mean ± SE of three replications.

4. CONCLUSIONS

The present study showed that coating sweet oranges significantly maintained quality and extended shelf life. It demonstrates that, coating with cowmilk butter and low storage temperature together significantly reduced citrus fruit weight loss. The coating was found to have a significant effect on sugar content. Orange fruits coated with cowmilk butter held at 7°C showed the lowest loss in firmness. Neither coating nor temperature was found to have a significant effect on TA, fruit juice taste as well and consumer acceptance. The results obtained revealed that surface coating contributed enormously to preserving the freshness of the fruits and improving their appearance. Cowmilk butter coating and stored at 7°C was the best treatment for maintaining the quality and extending the storage life of sweet oranges over other treatments or control, which was exhibited by the least weight and firmness losses, higher TA, lower total soluble solids, and had higher overall consumer acceptability over control. However, we would indicate that there is a need to evaluate the concentration of the application of cowmilk butter on orange fruits. Also, research could be conducted to evaluate other varieties of citrus fruits in commercial qualities.

Author contribution

Conceptualization, methodology, supervision, review and editing, and writing of the final manuscript were done by **NA**; data analyses and supervision were performed by **AA**; investigation and writing of the original draft were done by **GS**, **DK** and **AA**. All authors have read and agreed to the publication of this piece of work.

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Data availability statement

The data presented in this study are available in the article.

Conflicts of interest

The authors have no conflict of interest.

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